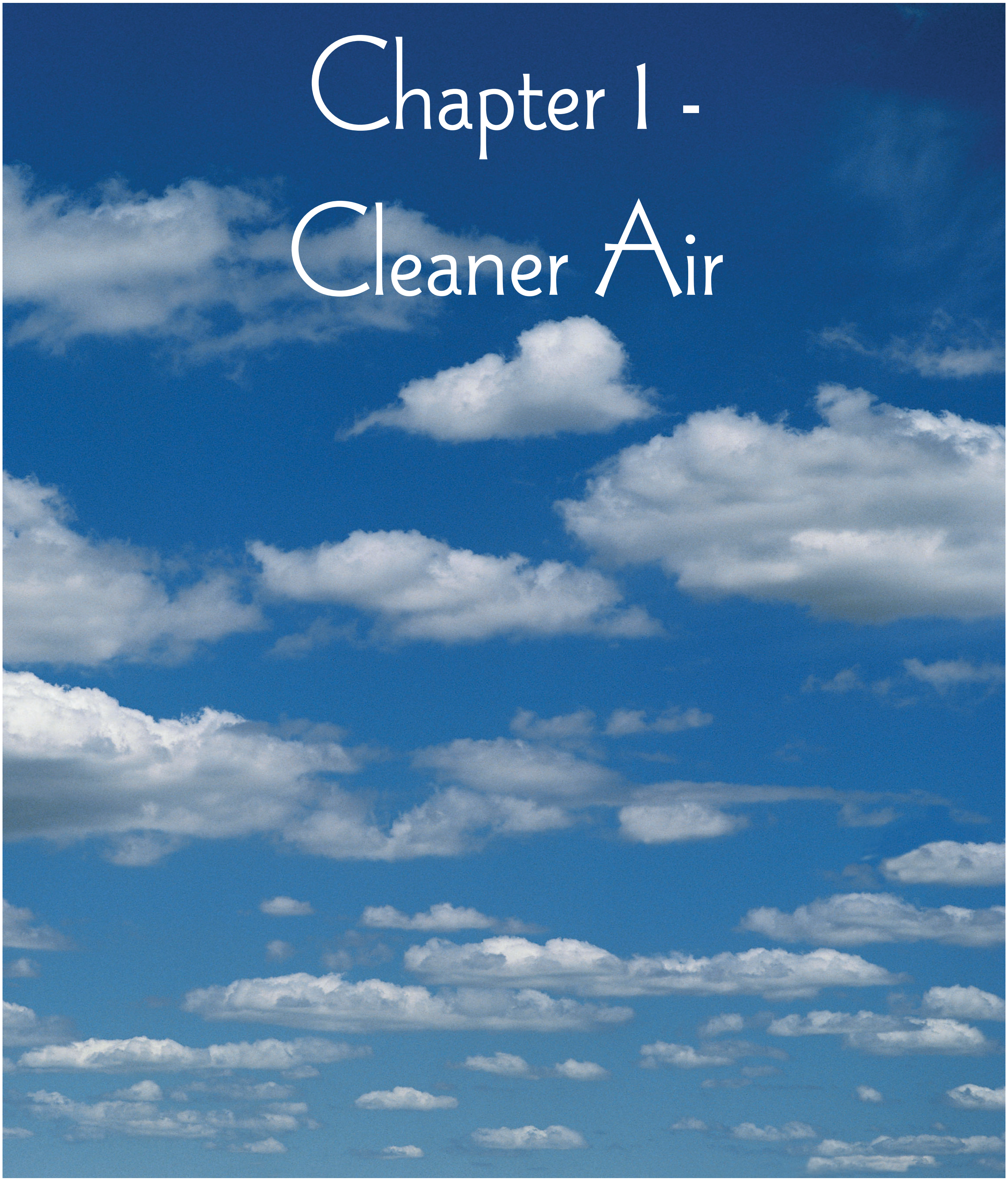
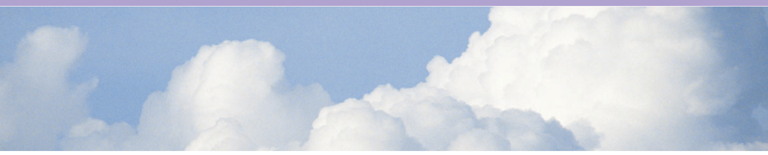
Chapter 1 - Cleaner Air





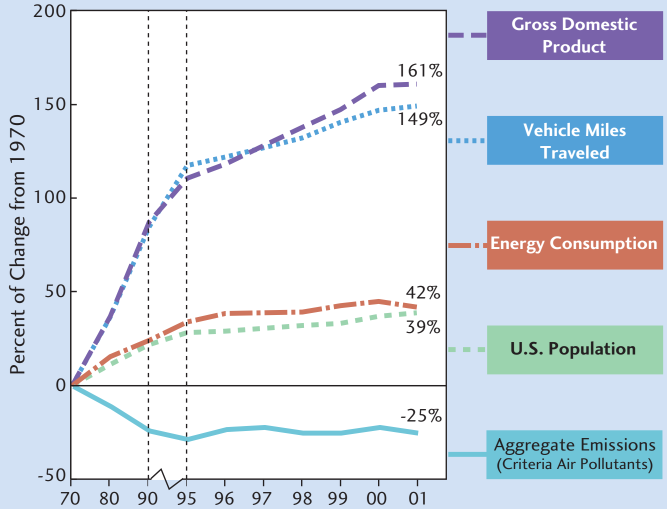
Introduction

How clean is the air we breathe outdoors? How does pollution in the air affect the quality of land and water? How healthful is the air in our homes and offices?

The air we breathe today is cleaner and more healthful than it was 3 decades ago. Since 1970, total national emissions of the six most common air pollutants have been reduced 25 percent. Remarkably, this improvement in national air quality has occurred even while, during the same 30-year period, the U.S. Gross Domestic Product increased 161 percent, energy consumption increased 42 percent, and vehicle miles traveled increased 149 percent (Exhibit 1-1).[1]

Building on this progress, work remains to ensure steady improvements in air quality. For example, certain areas of the country at times exceed national health-based air quality standards. We have much to learn about the levels of toxic air pollutants and the quality of air indoors.

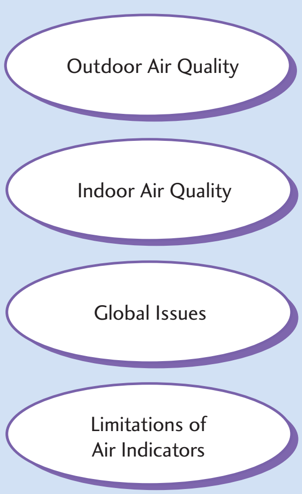
Exhibit 1-1: Comparison of growth measures and emission trends, 1970-2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

This chapter has three main sections: outdoor air quality, indoor air quality, and global issues. Each section tries to answer two general questions: What are the current conditions? What are the major contributors to change? Questions about health and ecological effects are posed and explored for a number of air quality issues. The chapter concludes with a section on the limitations of the indicators to address these questions.

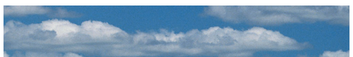
Chapter 1: Cleaner Air



Outdoor Air Quality

In the 1970s, the U.S. Environmental Protection Agency (EPA) identified six common—or "criteria"—air pollutants for which it established National Ambient Air Quality Standards (NAAQS) under the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and lead.

At elevated ambient levels, these pollutants—both alone and in combination—are associated with adverse effects on human health and on the environment. Breathing those pollutants at harmful levels can result in respiratory problems, hospitalization for heart or lung disease, and even premature death. They can also harm aquatic life, vegetation, and animals, as well as create haze and reduce visibility. In setting the national primary standards for each of the pollutants, EPA intended to protect public health and the environment, as required by the Clean Air Act. By law, the standards are to be periodically reviewed and revised as appropriate.



Outdoor Air Quality Indicators

Number and percentage of days that metropolitan statistical areas have Air Quality Index (AQI) values greater than 100

Number of people living in areas with ozone (8-hour) and particulate matter ($PM_{2.5}$) levels above the NAAQS

Ambient concentrations of ozone, 8-hour

Ambient concentrations of particulate matter ($PM_{2.5}$)

Visibility

Deposition: wet nitrogen and wet sulfate

Ambient concentrations of selected air toxics

Emissions of particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds

Lead emissions

Air toxics emissions

Emissions (utility): sulfur dioxide and nitrogen oxides

Information on air quality trends for criteria air pollutants is based on actual measurements of pollutant concentrations in the ambient air at more than 5,000 monitoring sites across the country. The data from those readings support EPA's key indicators for measuring outdoor air quality trends and determine which areas meet Clean Air Act standards.

Concentrations versus Emissions

Ambient—or surrounding—air concentration levels are the key measure of air quality and are based on the monitored amount (e.g., in units of micrograms per cubic meter [$\mu g/m^3$] or parts per million [ppm]) of a pollutant in the air. Emissions levels are based on estimates and monitored measurements of the amount (e.g., in units of tons) of a pollutant released to the air from various sources, such as vehicles and factories. Some emissions travel far from their source to be deposited on distant land and water; others dissipate over time and distance. The health-based standards (National Ambient Air Quality Standards) for criteria pollutants are based on concentration levels. The pollutant concentration to which a person is exposed is just one of the factors that determines if health effects occur—and their severity if they do occur.

What is the quality of the outdoor air in the United States?

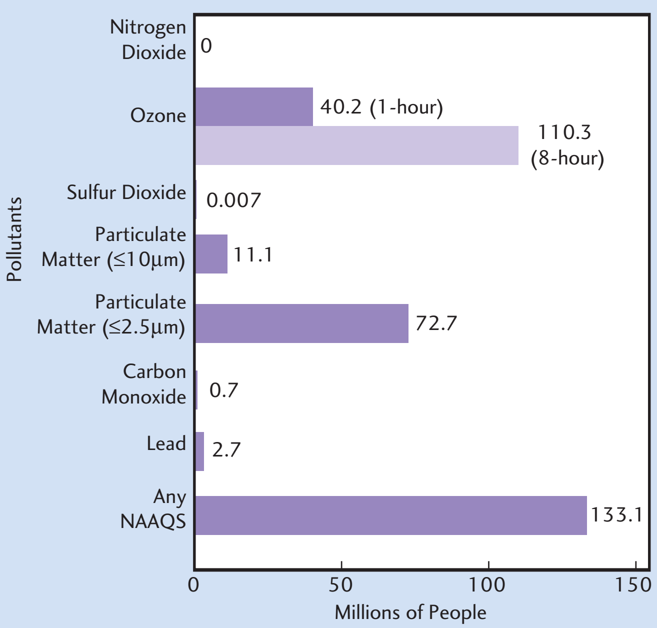
Trends in criteria air pollutants, visibility, acid deposition, and toxic air pollutants provide a picture of the nation's air quality. The nation's air quality is generally improving as measured by declining concentrations of criteria air pollutants. Acid deposition levels of sulfate are declining in the eastern U.S., the area most affected by deposition. Toxic air pollutants, though not as widely measured as criteria pollutants, also appear to be declining. Visibility in parks and other protected areas remained relatively steady over the last decade, and challenges remain in improving visibility.

Criteria Air Pollutants

Average ambient concentrations of the six criteria pollutants have shown improvements over the past 20 years.[2] For most parts of the country, the average ambient levels of lead, CO, SO_2, and NO_2 are lower than the standards. But many people live in areas of the country that do not always meet the health-based standards for certain pollutants, especially ozone and particulate matter.

In fact, more than 133 million people lived in areas where monitored air quality in 2001 was unhealthy at times because of high levels of at least one criteria air pollutant (Exhibit 1-2).[3] Based on EPA's Air Quality Index (AQI) data the percentage of days across the country on which air quality exceeded a health standard dropped from almost 10 percent in 1988 to 3 percent in 2001 (Exhibit 1-3).[4,5] Also, EPA has conducted an analysis of 260 metropolitan statistical areas (MSAs) for the 1990 to 1999 time period. This study shows that in 212 MSAs the average ambient concentrations for at least one of the criteria pollutants had downward trends, and in 57 MSAs there were upward trends for at least one pollutant (with 34 of the 57 MSAs showing significant upward

Exhibit 1-2: People living in areas with air quality concentrations at times above the level of the National Ambient Air Quality Standards (NAAQS) in 2001



Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

Air Quality Index

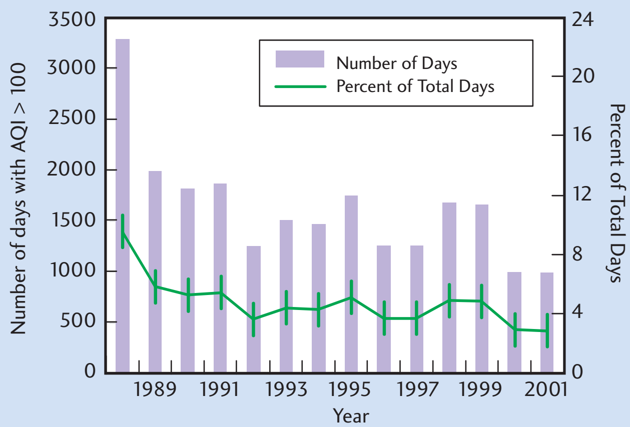
The Air Quality Index (AQI) is used for daily reporting of air quality as related to ozone, PM, CO, SO_2, and NO_2. It describes the health effects that may be associated with exposure to different levels of these pollutants, the groups likely to be most sensitive to the pollutant, and simple measures that can be taken to reduce exposure.

AQI values range from 0 to 500. The higher the AQI value, the greater the level of air pollution—and the greater the health danger. An AQI value of 100 generally corresponds to the national air quality standard for a pollutant. Thus, AQI values of less than 100 are usually considered satisfactory. When AQI values are higher than 100, air quality is deemed unhealthy for certain sensitive groups of people; as values rise, everyone becomes at risk. However, unusually sensitive people may experience health effects when AQI values are between 50 and 100.

The AQI scale is divided into six categories, each of which is identified with a particular color that corresponds to a level of concern for health. "Code orange," for example, means that the air is "unhealthy for sensitive groups," and "code red" means that the air may be unhealthy for everyone. The highest of the AQI values for the individual pollutants becomes the AQI value for that day. For example, if one day a certain area had AQI values of 150 for ozone and 120 for particulate matter, the AQI value would be 150 for the pollutant ozone on that day. Appropriate sensitive groups are always cautioned about any AQI value higher than 100.

In a recent "Roper Green Gauge Report," based on a nationwide poll of more than 2,000 people, 54 percent of those surveyed said they had heard of "ozone days" or "code orange"/"code red" air quality days, and 46 percent said they had reduced their exposure to air pollution by modifying outdoor exercise or work habits.[7]

Exhibit 1-3: Number and percentage of days with Air Quality Index (AQI) greater than 100, 1988-2001



Note: Data are for MSAs > 500,000.

Source: Data used to create graphic are drawn from EPA, Office of Air Quality Planning and Standards. *National Air Quality and Emissions Trends Report, 1997. Table A-15.* December 1998; EPA, Office of Air Quality Planning and Standards. Air trends: Metropolitan area trends, Table A-17. 2001 (February 25, 2003; *http://www.epa.gov/airtrends/metro.html*).

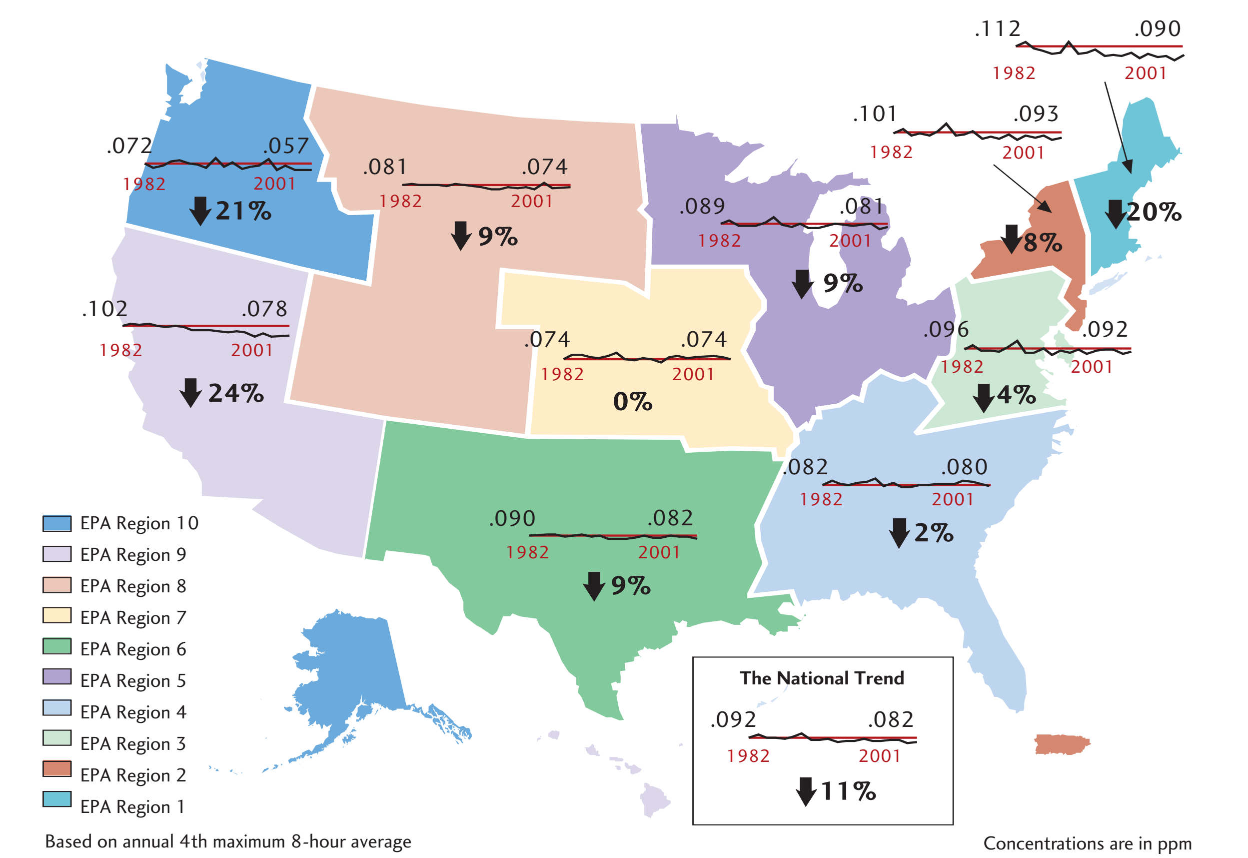
trends). Taken as a whole, the results of the study demonstrate significant improvements in urban air quality over the past decade.[6]

Ozone is not emitted directly into the air but formed by the reaction of volatile organic compounds (VOCs), nitrogen oxides (NO_X), and other chemical compounds in the presence of heat and sunlight, particularly in hot summer weather. Chemicals such as those that contribute to formation of ozone are collectively known as ozone "precursors." Particulate matter is emitted directly, and is also formed when emissions of NO_X, SO_2, and other gases react in the atmosphere.

With decreases in emissions of VOCs and other ozone precursors, 8-hour ozone concentrations fell by 11 percent nationally between 1982 and 2001.[8] All regions experienced improvement in 8-hour ozone levels during the last 20 years except the North Central region, which showed little change (Exhibit 1-4). However, in 2001 more than 110 million people lived in counties with concentrations higher at times than the 8-hour standard for ozone.[9] Southern California, the eastern U.S., and many major metropolitan areas have continuing ozone problems.

In 2001, some 73 million people lived in counties where monitored air quality at times exceeded the standard for fine particulate matter ($PM_{2.5}$)—those particles less than or equal to 2.5 micrometers (µm).[10] Concentrations of $PM_{2.5}$ vary regionally. California and much of the eastern U.S. have annual average $PM_{2.5}$ concentrations higher than the level of the

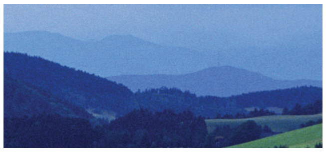
Exhibit 1-4: Trends in ozone levels, 1982-2001, averaged across EPA Regions



Note: Alaska levels are included in EPA region 10 averages; Hawaii levels are included in EPA region 9 averages; and Puerto Rico levels are included in EPA region 2 averages.

Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

annual $PM_{2.5}$ standard (Exhibit 1-5). The number of people living in counties with air quality levels that exceed the standards for ozone and PM signals continuing problems.



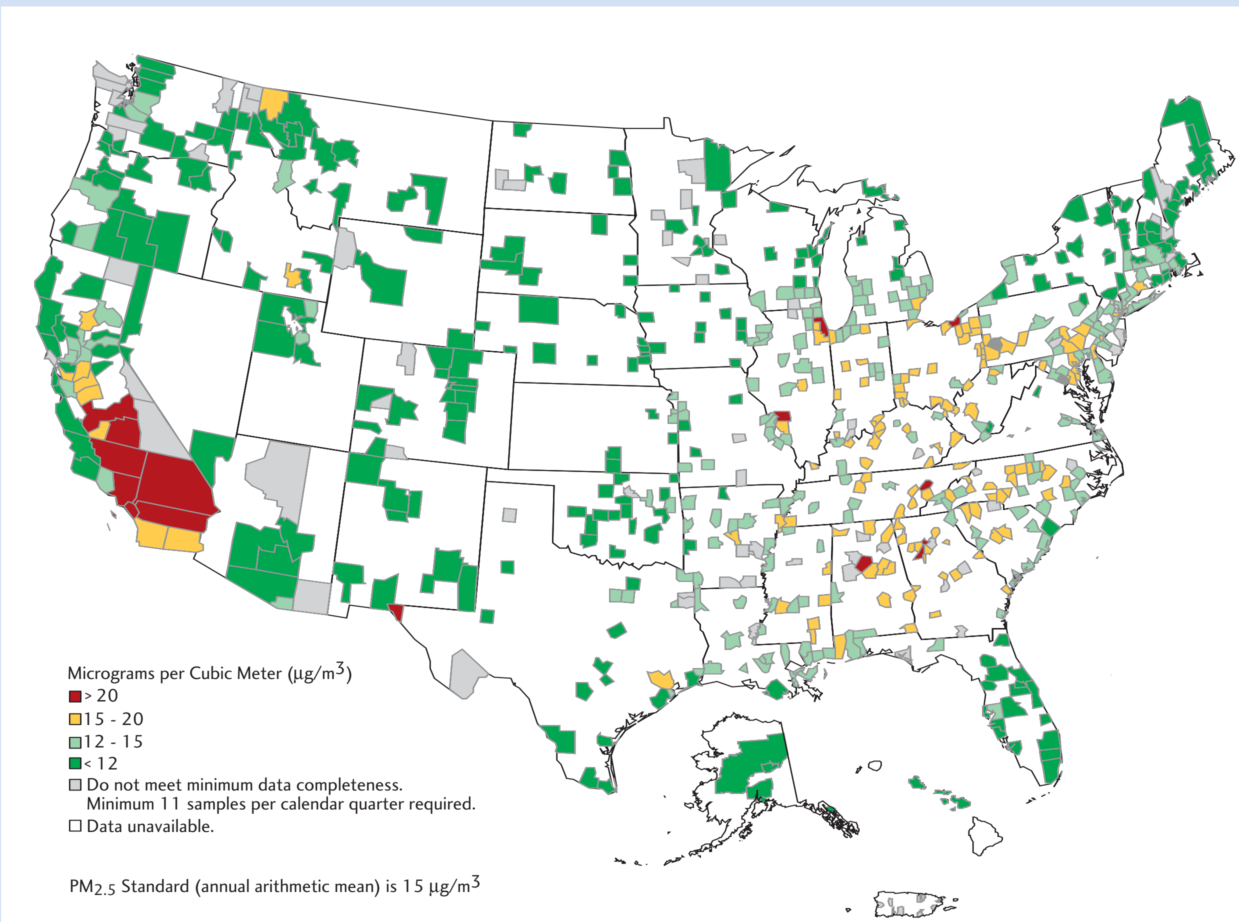
Visibility

Pollution is impairing visibility in some of the nation's parks and other protected areas. In 1999, average visibility for the worst days in the East was approximately 15 miles. In the West, average visibility for the worst days was approximately 50 miles in 1999.[11] Particulate matter is the major contributor to reduced visibility, which can obscure natural vistas. Without the effects of pollution, the natural visibility in the U.S. is approximately 47 to 93 miles in the East and 124 to 186 miles in the West. The higher relative humidity levels in the East result in lower natural visibility.

Acid Deposition

Two of the key pollutants that contribute to the formation of particulate matter—SO_2 and NO_X—react in the atmosphere with water, oxygen, and oxidants to form acid droplets. Rain, snow, fog, and other forms of precipitation containing the mixture of sulfuric and nitric acids fall to the

Exhibit 1-5: 2001 annual average particulate matter ($PM_{2.5}$) concentrations



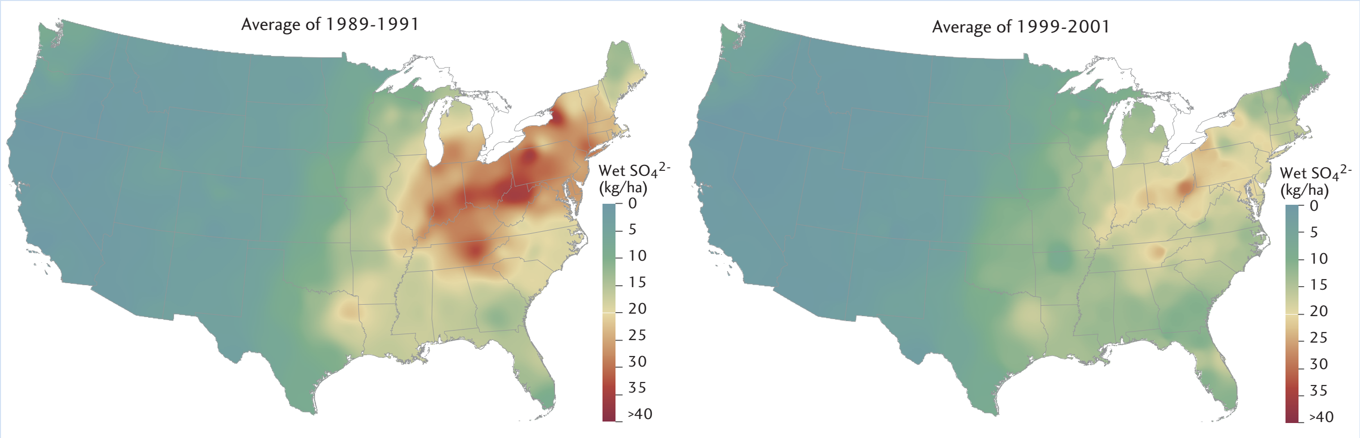
Source: EPA, Office of Air Quality Planning and Standards. *Latest Findings on National Air Quality: 2001 Status and Trends.* September 2002.

earth as acid rain (wet deposition). The particles also may be deposited without precipitation, known as "dry deposition." Wet sulfate deposition has decreased substantially—20 to 30 percent—throughout the Midwest and Northeast, where acid rain has had its greatest impact, between the periods 1989–1991 and 1999–2001 (Exhibit 1-6). During the same period, wet nitrogen deposition decreased slightly in some areas of the eastern U.S. but increased in other areas, including those with significant agricultural activity (Exhibit 1-7).[12]

Toxic Air Pollutants

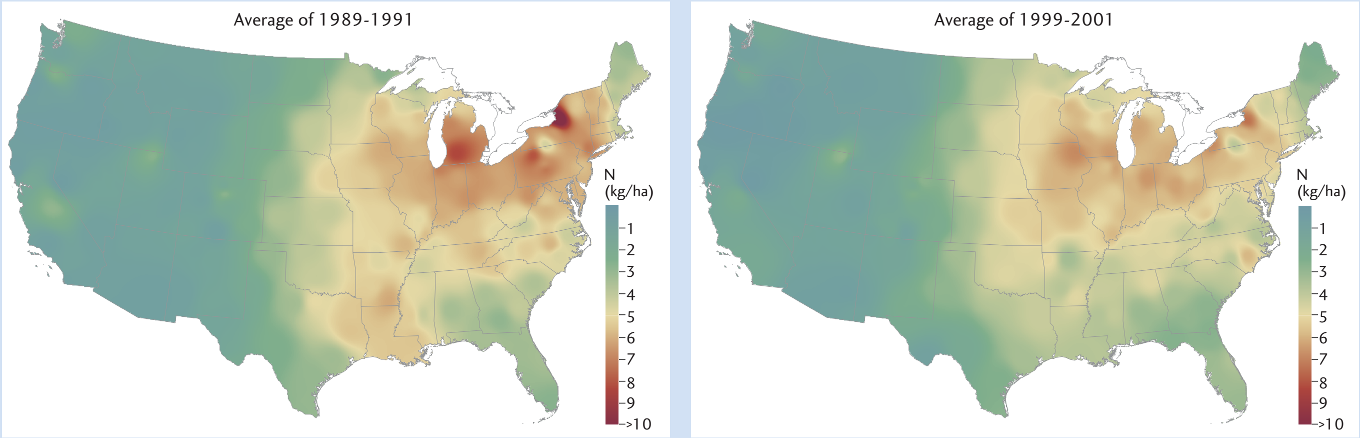
In addition to the six criteria pollutants, the Clean Air Act identifies 188 toxic air pollutants to be regulated. Among those pollutants are benzene, found in gasoline; perchloroethylene, emitted from some dry cleaning facilities; and methylene chloride, used as a solvent by a number of industries. Often referred to as "air toxics," these are pollutants that may cause cancer or other serious health effects—reproductive effects or birth defects, for example—and may also cause adverse ecological effects.

Exhibit 1-6: Wet sulfate deposition, 1989–1991 vs. 1999–2001



Source: EPA, Office of Air and Radiation, Clean Air Markets Program. *EPA Acid Rain Program: 2001 Progress Report*. November 2002.

Exhibit 1-7: Wet nitrogen deposition, 1989–1991 vs. 1999–2001



Source: EPA, Office of Air and Radiation, Clean Air Markets Program. *EPA Acid Rain Program: 2001 Progress Report*. November 2002.

Because there is currently no national monitoring network for toxics, concentrations of toxic air pollutants cannot be quantified on a comprehensive, national level. Data from several metropolitan areas do show downward trends in selected toxic air pollutants. For example, the levels of benzene measured at 95 urban monitoring sites decreased 47 percent from 1994 to 2000.[13] Although data and tools for assessing the impacts of air toxics are limited, available evidence suggests that emissions of air toxics may still pose health and ecological risks in certain areas of the U.S.[14]

What contributes to outdoor air pollution?

Both manmade and natural sources contribute to criteria and toxic air pollutants. Emissions from factories, electric utilities, oil refineries, waste incinerators, smelters, dry cleaners, agricultural facilities, construction equipment, woodstoves, slash pile burning, cars, buses, planes, trucks, trains, and lawn mowers—among many other sources—contribute to outdoor air pollution. Applying commercial products such as paints and strippers can also produce air pollution through the release of VOCs. Air pollution can also stem from natural processes such as volcanoes, windblown dust, and wildfires.

Most of the six criteria air pollutants show declining emissions since 1982 (Exhibit 1-1). But as reported in *Latest Findings on National Air Quality: 2001 Status and Trends*, emissions of NO_X, a contributor to ozone, particulate matter, and acid rain formation, increased by 9 percent between 1982 and 2001, with a slight decrease (3 percent) between 1992 and 2001.[15] A significant amount of that increase is attributed to growth in emissions from non-road engines, including construction and recreation equipment and diesel vehicles.[16] Data from the National Emissions Inventory (NEI) are used for tracking trends in emissions over time. State and local agencies, tribes, and industry provide input to the NEI database, which includes estimates of annual emissions, by source, of air pollutants in each area of the country, on an annual basis. EPA continuously reviews and improves estimates of pollutant emissions. Emissions estimates for criteria pollutants are currently under such evaluation and may be updated.

Actual emissions of SO_2 and NO_X from electric utility plants, which are significant sources of both pollutants, are monitored for a program designed to reduce acid rain. Sulfur dioxide emissions from sources affected by the Acid Rain Program declined from nearly 16 million tons in 1990 to 10.6 million tons in 2001.[17] NO_X emissions from utility sources decreased from 6.7 million tons in 1990 to 4.7 million tons in 2001.[18] The National Toxics Inventory, which uses data from the Toxics Release Inventory and other sources, estimates that nationwide air toxics emissions dropped approximately 24 percent between their baseline (1990 to 1993) and 1996 to 4.7 million tons annually.[19]

What human health effects are associated with outdoor air pollution?

Outdoor air pollution can cause a wide variety of adverse health problems. Some of the criteria pollutants, particularly ozone, NO_2, and SO_2, are primarily associated with respiratory-related effects, including aggravation of asthma and other respiratory diseases, irritation of the lungs, and respiratory symptoms (e.g., cough, chest pain, difficulty breathing). Short-term exposure to ozone has also been linked to lung inflammation and an increased number of hospital admissions and emergency room visits.[20,21,22,23,24] Repeated short-term exposures to ozone may damage children's developing lungs and may lead to reduced lung function later in life, whereas long-term exposures to high ozone levels are a possible cause of an increased incidence of asthma in children who engage in outdoor sports.[25] Carbon monoxide, on the other hand, primarily affects people with cardiovascular disease by reducing oxygen in the blood, which aggravates angina.[26]

Particulate matter is associated with both respiratory-related and cardiovascular effects, exhibiting a broader range of effects. For example, short-term exposures to particulate matter may aggravate asthma and bronchitis and have been associated with heartbeat irregularities and heart attacks.[27] Such exposures have been linked to increased school absences and lost workdays, hospital admissions, and emergency room visits, and even death from heart and lung diseases.[28] Long-term exposures have also been linked to deaths from heart and lung disease, including lung cancer.[29,30]

People exposed to certain toxic air pollutants at sufficient concentrations may also experience harmful health effects, including cancer, respiratory and cardiovascular effects, damage to the immune system, and neurological, reproductive, and developmental problems. Even at low doses, lead—both a criteria and toxic air pollutant—is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ.[31] Exposure to benzene, a widely monitored air toxic, has been linked to increases in the risk of two types of cancer: leukemia and multiple myeloma.[32] (For additional information on health effects associated with outdoor air pollution, see Chapter 4 – Human Health.)

What ecological effects are associated with outdoor air pollution?

Many health effects are associated with breathing polluted air, but air also transports pollutants and deposits them onto soils or surface waters, where they can potentially affect plants, crops, property, and animals. Toxic substances in plants and animals can move through the food chain and pose potential risks to human health. Airborne mercury from incineration, for example, can settle in water and contaminate fish. People and other animals higher on the food chain (e.g., bald eagles, bears, and cougars) that eat contaminated fish are then exposed to potentially harmful levels of mercury, which is known to affect the nervous system. (For additional information, see the section on "Contaminated Fish and Shellfish" in Chapter 2 – Purer Water.)

Direct exposure to ozone under certain conditions can be harmful to plants and forests; it reduces overall plant health and interferes with the ability of plants to produce and store food. Such weakened plants are in turn more susceptible to harsh weather, disease, and pests. Through its effects on plants, ozone can also pose risks to ecological functions such as water movement, cycling of mineral nutrients, and habitats for various animal and plant species. Airborne particles also can have an adverse impact on vegetation and ecosystems.[33]

Increased acid levels damage soils, lakes, and streams, rendering some waterbodies unfit for certain fish and wildlife species. Indirect effects of acid deposition are also responsible for damage to forest ecosystems. Excess deposition of acid ions in the soil causes calcium and other essential plant nutrients to be leached from the soil, and thus no longer available to sustain normal plant growth and maintenance. The calcium depletion also causes a scarcity of worms and other prey, affecting the ability of some birds to lay eggs and bring them to term.

Acid ions also can increase the movement of aluminum in soil, which competes with calcium and other nutrients in plant roots during absorption, further limiting plant growth. Acid deposition can also produce elevated levels of aluminum in waterbodies. This results either from direct deposits acidifying the waterbody itself or from water passing through soil that is high in aluminum and then entering the waterbody from adjacent terrestrial systems. Those elevated levels of aluminum in water can be toxic to fish and other aquatic life.[34]

The nitrogen in acid rain is one of the sources contributing to the total amount of nitrogen in terrestrial and aquatic systems. Although nitrogen is a necessary nutrient in productive ecosystems, too much nitrogen in terrestrial systems can cause changes in biodiversity. In aquatic systems, it fuels excessive growth of algae in coastal waters. When the dense algal blooms die, bacteria decay them. That process uses up the oxygen that is needed by fish to survive. (For additional information on the effects of nitrogen on waterbodies, see the section on "Waters and Watersheds" in Chapter 2 – Purer Water.)

Indoor Air Quality

Air pollution is also an issue indoors. There are many potential sources of indoor pollution, such as tobacco smoke, building materials, cleaning fluids, pesticides, and outdoor air pollution that seeps inside. But few studies have examined the overall presence of indoor pollutants or the extent of human exposure to them. Scientists know that indoor air pollutants can cause long- and short-term health effects, but experts face challenges in determining the consequences of exposure to various indoor air pollutants at low levels for long periods of time.

What is the quality of the air in buildings in the United States?

There is no comprehensive monitoring of the quality of indoor air in the U.S., and the actual levels for many pollutants are not well understood. Nonetheless, studies have demonstrated that indoor levels of some pollutants can be much higher than outdoor levels. Because most people spend the majority of their time indoors, the indoor air quality of the nation's homes, work places, and schools is a serious issue.

Two indoor air pollutants of particular concern are environmental tobacco smoke (ETS) and radon. A 1998 survey estimated that young children were exposed to ETS in approximately 20 percent of homes in the U.S.—down from approximately 39 percent in 1986.[35] Based on a representative 1991 survey of all homes in the U.S., an estimated 6 million homes had high radon levels—levels equal to or greater than EPA's action level of 4 picocuries per liter.[36] Those homes represented about 6 percent of housing units in the U.S.

Indoor Air Quality Indicators

U.S. homes above EPA's radon action levels

Percentage of homes where young children are exposed to environmental tobacco smoke

What contributes to indoor air pollution?

Indoor air pollutants include naturally occurring radon, ETS, particulate matter, asbestos, molds, dust mites, lead and other toxic air pollutants, VOCs, pesticides, and gases emitted from

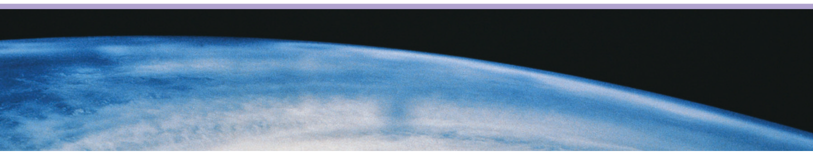
Indoor Air Quality in Office Buildings

The goal of the EPA's Building Assessment Survey and Evaluation (BASE) Study was to define the status of U.S. office buildings with respect to indoor air quality and occupants' perceptions of that quality. In this study, conducted between 1994 and 1998, a sample of 100 office buildings was used to characterize the central tendency—mean or median levels—of indoor air quality in commercial or public office buildings, representing the size building in which 73 percent of all office employees work. In a subset of the first 56 of those buildings, EPA measured the indoor concentrations of 48 VOCs. In a preliminary analysis, 34 VOCs were detected in 81 percent or more of the samples. All measurable VOCs were present at higher levels indoors than outdoors, suggesting the presence of indoor sources.[37] In most buildings, the indoor concentration of particulate matter was lower than or nearly equal to the measured outdoor level. However, 11 of the buildings had PM_{10} (particles less than or equal to 10 µm) levels at least 50 percent higher than outdoor levels, which could be a significant factor in a person's total exposure.[38]

inadequately vented heaters and pilot lights. Sources also include certain furnishings and improperly stored solvents, cleaners, pesticides, paints, and other household chemicals. Concentrations of certain chemical compounds and radon can become particularly problematic when homes or buildings are tightly sealed and have little exchange of indoor and outdoor air. Like many other air pollutants, concentrations of indoor radon vary widely from one location to another, and around the country as well.

What human health effects are associated with indoor air pollution?

Poor indoor air quality can cause short-term problems, including headaches, fatigue, dizziness, nausea, and a scratchy throat. But its other effects include cancer—particularly from long-term exposures to high ETS and radon concentrations—and aggravation of chronic respiratory diseases such as asthma. Exposure to naturally occurring radon gas is the second leading cause (after smoking tobacco) of lung cancer among Americans.[39] The most sensitive and vulnerable population groups—older people, the young, and the chronically ill—tend to spend the most time indoors and may therefore face higher-than-usual exposures.



Global Issues

Ozone depletion has global consequences for human health and the environment. Ozone depletion takes place when pollution damages the thin layer of beneficial ozone in the stratosphere, about 6 to 30 miles above the Earth, which protects living beings from harmful ultraviolet (UV) radiation from the sun.

The issue of global climate change involves changes in the radiative balance of the Earth—the balance between energy received from the sun and emitted from Earth. This report does not attempt to address the complexities of this issue. For information on the $1.7 billion annual U.S. Global Climate Research Program and Climate Change Research Initiative, please find *Our Changing Planet: The Fiscal Year 2003 U.S. Global Climate Research Program* (November 2002) at http://www.usgcrp.gov and the *Draft Ten–Year Strategic Plan for the Climate Change Science Program* at http://www.climatescience.gov.

Ozone depletion in the stratosphere and climate change are separate environmental issues but are related in some ways. Specifically, some substances that deplete the stratospheric

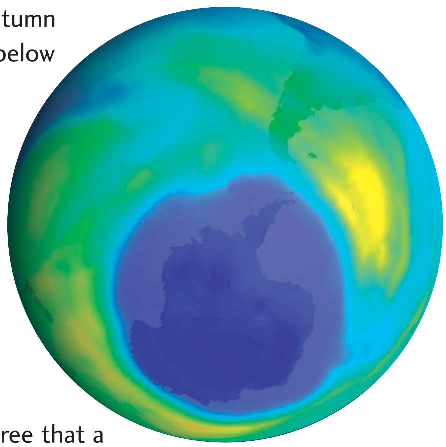
Global Issues Indicators

Ozone levels over North America

Worldwide and U.S. production of ozone-depleting substances ozone layer also are potent and very long-lived greenhouse gases that absorb outgoing radiation and warm the atmosphere. Ozone itself is a greenhouse gas when it absorbs incoming solar radiation and its depletion in the stratosphere over the polar zones results in localized cooling at times.

What is happening to the Earth's ozone layer?

In recent decades, the Earth's stratospheric ozone layer has become substantially thinner. The thinning has occurred principally over Antarctica and is referred to as the "ozone hole." The ozone layer over the Northern Hemisphere's middle latitudes is about 2 percent below normal during summer and autumn and about 4 percent below normal in winter and spring.[40] Between 1979 and 1994, the ozone layer thinned 8 percent over Seattle, 10 percent over Los Angeles, and 2 percent over Miami.[41]



Scientists generally agree that a thinning of the stratospheric ozone layer causes an increase in the amount of ultraviolet (UV) radiation. While acknowledging high uncertainty in the data, scientists have calculated that UV radiation levels at more than 10 sites in both hemispheres have increased by 6 to 14 percent since the 1980s.[42] EPA, in partnership with the National Weather Service, publishes an index that predicts UV intensity levels for different cities on a scale of 0 to 10+, where 0 indicates a minimal risk of overexposure and 10+ means a very high risk.

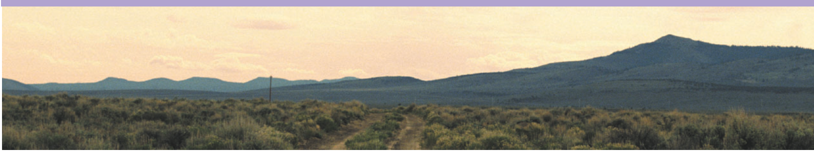
What is causing changes to the ozone layer?

Stratospheric ozone depletion is associated with the use of chlorofluorocarbons (CFCs), halons used to extinguish fires, and other chemicals used as solvents. Air conditioners, refrigerators, insulating foams, and some industrial processes all emit those substances. Air currents carry molecules with chlorine and bromine from those pollutants into the stratosphere, where they react to destroy ozone molecules.

The U.S. virtually ceased production of most ozone-depleting substances in January 1996, because of its participation in an international agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer. Nonetheless, ozone-depleting substances are still being released into the environment, as reported in the Toxics Release Inventory. Along with other developed countries, the U.S. makes substitutes for the strong ozone-depleting CFCs. These substitutes are themselves less ozone-depleting than the substances they replace. Also, because the Montreal Protocol controls production but not use, emissions continue from materials made before January 1996. Even though scientists believe that recovery is under way, full restoration of the stratospheric ozone layer will take decades because of the continued use of products manufactured before the ban.

What are the human health and ecological effects of stratospheric ozone depletion?

Thinning of the stratospheric ozone layer allows more of the sun's UV radiation to reach Earth, where it contributes to increased incidences of human skin cancers, the most common of all cancers. Cataracts and suppression of the human immune system may also result from increased exposure to UV radiation. In addition, productivity of some marine phytoplankton, essential to the ocean's food chain, may be unduly stressed by high levels of UV radiation.[43]



Limitations of Air Indicators

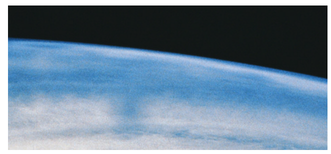
Many sources of data support indicators that help to answer questions about the trends in outdoor and indoor air quality and stratospheric ozone. But there are limitations in using the indicators to fully answer the questions.

Outdoor Air

In general, there are some very good measures of outdoor air quality. Although the national air monitoring network for the six criteria air pollutants is extensive, there are far more monitors in urban areas than in rural areas. That helps to characterize population exposures, because population tends to be concentrated in developed areas, but it may make it more difficult to assess effects associated with the transport of air pollutants and ecological effects. Recently, EPA and states have begun evaluating and planning a nationwide monitoring network for air toxics. With a few notable exceptions such as power plants, emissions quantities for both the criteria pollutants and air toxics are based on engineering estimates derived from more limited actual data. There is a need for measures to compare actual and predicted human health and ecological effects related to exposure to air pollutants.

Indoor Air

Although environmental indicators have been developed for some aspects of indoor air, significant gaps exist in knowledge about the conditions inside the nation's buildings. For schools and residences, a large amount of information on indoor air quality is available, but it comprises primarily case studies and small, at best, regional studies. More comprehensive data from national exposure studies for schools and residential indoor environments, including multiple-family residences, would be helpful in understanding the condition of indoor air environments. Ideally, such studies would collect exposure data on air toxics and particulate matter in those indoor environments, as well as data for molds and other biological contaminants found in indoor air.



Global Issues

In general, high quality data exists with which to predict the human health effects of increased ultraviolet exposure resulting from depletion of the stratospheric ozone. These include robust satellite data on stratospheric ozone concentrations and UV levels, comprehensive and well documented incidence and mortality rates for cutaneous melanoma, and well characterized action spectra for skin cancers and cataracts. However, there are areas where additional data would be useful. First, no national system exists that collects incidence data for squamous cell carcinoma and basal cell carcinoma, the non-melanoma skin cancers caused by increased UV exposure. Thus, our incidence estimates are modeled using data from a nation-wide survey of non-melanoma skin cancer incidence and mortality, and may not represent the most current non-melanoma skin cancer rates. Second, there is a lack of adequate ground level UV monitoring with which to compare the satellite data. Satellites cannot directly measure ground level UV, and are sensitive to pollution. Therefore, while satellite data compare fairly well to ground level UV measurements in clean locations, this is not the case in polluted areas. Additional UV monitoring in cities is crucial to support future epidemiological research on the human health effects of UV exposure. Third, increased UV levels have been associated with other human and non-human endpoints including immune suppression and effects on aquatic ecosystems and agricultural crops. However, additional research on these topics is necessary before these effects can be modelled or quantified. Finally, the future behavior of the ozone layer will be affected by changing atmospheric abundances of various atmospheric gases. It remains unclear how these changes will affect the predicted recovery of the ozone layer. Additional research on the interaction between climate and stratospheric ozone could provide more accurate predictions of ozone recovery and the human health effects resulting from ozone depletion.

Endnotes

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